EXPLORATION OF EDUCATIONAL BUILDING WITH CULTURAL ELEMENTS USING SHAPE GRAMMAR

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ABSTRACT

Shape grammars are used for developing computational algorithms in production systems that generate geometric shapes. Existing researches on shape grammars in applications focus on product design, pattern generation, residential building design and architectural design. However, research on the educational building design with different aspects in functions and environments are not much addressed. This research explores the application of shape grammars in generating educational building designs with cultural, functional and artistic issues. Basic building blocks for Western, Chinese, European and Malay culture are developed to construct the educational buildings. Existing building blocks like L-shapes oriented with specific angles could be combined to form a new building concept. This new concept can uniquely represent a particular educational building characteristic. During the design process, other rules are activated to embed new shapes within the basic building block. The rules are executed to generate designs to provide students a spacious environment for study and related activities. Other concepts like pure, rational and energy saving are also expressed by the rules. The system takes into account of different requirements like costs, functions, space, culture, environment, the number of classrooms, public halls, windows and doors. For example, the urban areas in Kuala Lumpur consist of many high rise buildings, like office buildings, residential apartments and others. Under these constraints, a stylistic educational building with high scores can be generated by the system as it suits this particular set of requirements. In future, more on-site applications and surveys will be conducted to verify the advantages in using the system to explore educational building designs. Other enhancements would be the automation of the formulation and execution of the shape grammar rules by integrating artificial intelligence techniques such as fuzzy logic, neural network and genetic programming.

Keywords - Shape grammar, educational building, environmentally friendly

ABSTRAK

Bentuk tatabahasa yang digunakan untuk membangunkan algoritma pengiraan dalam sistem pengeluaran yang menghasilkan bentuk geometri. Penyelidikan yang sedia ada pada bentuk tatabahasa dalam aplikasi memberi tumpuan kepada reka bentuk produk, generasi corak, reka bentuk bangunan kediaman dan reka bentuk seni bina. Walau bagaimanapun, kajian mengenai reka bentuk bangunan pendidikan dengan aspek yang berbeza-beza fungsi dan persekitaran yang tidak banyak dicadangkan. Kajian ini meneroka penggunaan tatabahasa bentuk dalam menjana reka bentuk bangunan pendidikan dengan isu-isu budaya, fungsi, dan seni. Blok binaan asas untuk budaya Barat, Cina, Eropah dan Melayu yang dibangunkan untuk membina bangunan-bangunan pendidikan. Blok bangunan yang sedia ada seperti bentuk L yang berorientasikan dengan sudut tertentu boleh digabungkan untuk membentuk satu konsep bangunan baru. Konsep baru yang unik boleh mewakili ciri-ciri tertentu bangunan pendidikan. Semasa proses reka bentuk, kaedah-kaedah yang lain diaktifkan untuk menerapkan bentuk baru di dalam blok bangunan asas. Kaedah-kaedah yang dilaksanakan untuk menjana reka bentuk untuk menyediakan pelajar persekitaran yang luas untuk kajian dan aktiviti yang berkaitan. Konsep-konsep lain seperti penjimatan tulen, rasional dan tenaga juga dinyatakan oleh peraturan. Sistem ini mengambil kira keperluan yang berbeza seperti kos, fungsi, ruang, budaya, alam sekitar, bilangan bilik darjah, dewan, tingkap dan pintu. Sebagai contoh, kawasan bandar Kuala Lumpur yang terdiri daripada banyak bangunan tinggi, seperti bangunan pejabat, pangsapuri kediaman dan lain-lain. Di bawah kekangan ini, sebuah bangunan pendidikan gaya dengan markah yang tinggi boleh dihasilkan oleh sistema kerana ia sesuai dengan set keperluan tertentu. Pada masa hadapan, lebih banyak aplikasi di tapak dan kajian akan dilaksanakan untuk mengesahkan kelebihan dalam menggunakan sistema untuk meneroka reka bentuk bangunan pendidikan. Tambahan lain akan automasi penggubalan dan pelaksanaan peraturan tatabahasa bentuk dengan mengintegrasikan teknik kepintaran buatan seperti logik kabur, rangkaian neural dan pengatucaraan genetik.

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CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

What is shape grammar? From our first point of view, the term seems unfamiliar to us. However, after several times of studying and interpretation, shape grammar, which was defined by Jay P.M and Jonathan C., 2006, means "a set of shape rules which can be applied in a sequence, beginning with an initial shape, to create shapes in the languages defined by the grammar." Shape grammar is widely used in engineering field, for example; Agarwal and Cagan (1998) introduced the coffee maker grammar and Andrew I-Kang-Li (2003) explained the shape grammar used in analysing the architectural design.

Architectural design, on the contrary, is an application of diverse skills to produce an architectural form. In my country, Malaysia, the construction of educational buildings nowadays consumes a spacious area and building materials. However, the architectural design of the building is yet simple and doesn't have any special representation of meaning.

Therefore, the design for academic building with some cultural elements, like the Western, Chinese, Malay and Europe cultures by using shape grammar would be implemented as to promote the unique culture elements in our country to be nationwide. In addition, the educational building design will also include some environmental requirements and the functionality of the building in order to meet the aesthetic and sociological impact.

1.2 PROBLEM STATEMENT

There lie some problems in the implementation of shape grammars with culture elements in the design of educational building. Firstly, the shape grammar can really generate a sufficient amount of patterns, although different cultural elements are implemented. Besides that, in what way can the building design associated with environmental issues and rather than novice users, who will also be using this design software system.

1.3 OBJECTIVES

(i) To develop educational building shape grammar with cultural and environmental friendly elements.

(ii) To explore educational building designs under constraints of cost, function, culture, environment, space, material and location.

(iii) To evaluate alternative educational building designs for urban planning in different cities.

1.4 SCOPE

The project scope has been identified to develop the prototype of building design as listed below:

(i) Explore educational building designs according to specific culture and constraints.

(ii) Program model using MEL script in Maya.

(iii) Target users are students, architects, civil engineers and design company.

1.5 THESIS ORGANIZATION

This thesis consists of six (6) chapters. Chapter 1 discuss on the introduction to the research in exploring educational buildings with cultural elements by using shape grammars. Various techniques in constructing the shape grammars and some environmental requirements that will be used also being discussed in this chapter.

Chapter 2 describes on the literature review of shape grammar from related journal articles. Besides, various techniques used in shape grammar for different shape grammar applications were being discussed.

Chapter 3 discuss on the methodology that will be used in the exploration of educational building with culture elements using shape grammar. The techniques, analysis, the project and software methodology used for this project were being discussed.

Chapter 4 discuss about the design and implementation of this exploration of educational building with culture elements using shape grammar. The design of the interfaces, the generation of shape grammar rules and also some MEL coding will further discuss in this chapter.

Chapter 5 discuss about the results and constraints. Results such as whether this program application achieved the objectives listed earlier and discuss on the constraints met when developing this program.

Chapter 6 conclude all the works done in this research project.

CHAPTER 2

LITERATURE REVIEW

Shape grammar which was declared by Ietyn Jowers, (2006) as the "formal production system, where particular aspects design processes are represented by form and are defined according to shapes and rules applied to those shapes." This shape grammar technique was applied in various fields, such as engineering and architectural field, computer graphic field as well as painting and sculpture. For example, shape grammar was being used to analyse the art of Tibetan Tangka paintings and to help the designers to generate and evaluate their ideas during the conceptual phase of the design process in the engineering field. Moreover, in recent years, shape grammar was used widely across computer graphic, computer game and animation. They used shape grammar in games, where they construct the structures of the buildings and also to model the artificial machine which have some human characteristics. Design, on the other hand, is a technique to produce a new paradigm of patterns through some specific requirements. For example, design an educational building with some culture and environmentally friendly elements.

The article of Harmonised Shape Grammars in Design Practise, discussed about the development of shape grammar in designing a harmonious and contextual based design objects by using the theory of Natural Language Processing. As Arus Khunket, (2011) suggest that "shape grammar is useful when applying in the architectural domain, rather than a product design domain". The author also commented the shape grammar is useful in architectural design, but not so useful in product design pattern. On the other hand, he declared that using natural language in designing product may achieve to a harmonious and contextual design product pattern. Besides that, there are several processes involved in the natural language processing process, which consists of reasoning, factual data retrieval, and generation of an appropriate table form, graphic or natural language response. In addition, the technique of genetic algorithm, like the selection, recombination and mutation phases also being used in the production.

The technique mentioned will be used in the design of the architectural education building. For example, the initial shape pattern will change in its patterns when the rules are applied, where the shape will change in its position, either in horizontal or vertical or at any degree.

According to Liebich. (1994), he explained that " a shape grammar includes logical rules, which act in a limited amount of elements of the same vocabulary and create a set of similar objects, based on the same syntax. These shape rules are used to produce new and alternative states of the design process. Thus, a shape grammar generates a language of design." He interprets the techniques of constructing shape grammar rules into two, that are syntactic and semantic structures, where for syntactic structure refers to a set of language elements and a set of rewriting rules that are fully expressed ; while, for the semantic structure, is faced with task communication. In addition, artificial intelligence technique also being discussed. The knowledge based was implemented as mentioned in the paper, where it can include the links between the data on the condition side and the action side of different productions.

In the thesis, both the syntactic and semantic structures are the important elements in the design of architectural educational buildings. Besides, the vocabulary of design language should include culture and environmentally friendly elements. The semantic structure will only interchange the surface patterns of the shape without destroying its structure. For example, the replacement of rectangular to circular windows in the whole building can be achieved by changing the corresponding rules. The whole design skeleton remains as specified in the semantic structures. The environmental friendly element will also be implemented in the design of educational building using shape grammar, which will use the natural resources, such as a beam of sunlight and others instead of electricity.

There are two types of chaining, that are forward and backward chaining. Forward chaining which claimed by M. Negnevitsky, as the data driven reasoning. In the context, he claims that "this reasoning starts from the known data and proceeds forward with that data. Each time, only the topmost rule is executed. When fired, the rule adds a new fact in the database. The match-fire cycle stops when no further rules can be fired. On the other hand, backward chaining as the goal driven reasoning, which the knowledge base

has the goal (a hypothetical solution) and the inference engine attempts to search the evidence to prove it." System such as CODE (Column Designer) has been developed to support the automation of generating the colonnade by following different orders, modules and spacing.

However, these rules based systems have a limitation in generating the emergent design. Therefore, further discussion will be needed. Due to time constraints, such technique will not be considered in the implementation.

In another study of the effects of design on automobile styling perceptions, the researchers use the software like ConceptMorph, which is a computer-aided concept design system to perform the product shape morphing and to modify the product shapes and also features by using free-hand sketches. Besides, the researchers also conducted conjoint analysis, where this method can investigate the effects of design features on the perception of automobile styling designs. During the design phase, the researchers select the design features that will be investigated, then by using conjoint analysis to compute the joint effect of the design pattern.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this methodology of the research, details about the instruments or methods used to conduct the investigation on exploration of educational building with cultural elements by using shape grammar will be discussed. This research consists of information about participants, data collection method, survey questionnaires, data analysis, the implementation of cultural elements, shape grammar rules, materials and methods used, hardware and software used, and Gantt chart.

3.1.1 Participants

A survey will be conducted among University Malaysia Pahang students and lecturers. This survey involved randomly selected third year students and some lecturers from the Faculty of Civil Engineering and Natural Resources (FKASA). A quantity of 15 questionnaires will be distributed and answering by the students and lecturers of FKASA for both genders.

3.1.2 Data Collection Method

The data collection method use in this study was aimed at exploring the design structure of the educational building with cultural elements by using the shape grammars, which will be used by the architecture students and lecturers. The data collection instrument that will be used in this study is surveying questionnaire.

3.1.3 Survey Questionnaire

A number of questions will be asked as a source to explore the design of educational building with cultural elements by using shape grammar among third year students and lecturers of FKASA. The survey consists of 10 questions and all are closed-ended questions. The closed ended-questions were multiple choice questions. These questionnaires will be handed out by me only. Questionnaire method is chosen because it is an effective, fast and convenient way to obtain the result. In PSM 1, the survey is for planning of shape grammar, while in PSM 2, the survey is for the implementation.

3.1.4 Data Analysis

All the data obtained from the survey questionnaire will be analysed by using Microsoft Excel spreadsheet in order to calculate the overall view of the respondents towards the exploration of educational building by using shape grammar. The analysed data will then be presented in value and percentage, which are in the form of histograms and pie charts. Next, the design and implementation will be made according from the result shown.

3.2 Methods and material used

In this project, the methodology is separated into two parts, which are the methodology for the system development and the methodology for the project development. Both methodologies will be discussed in the chapter below.

3.2.1 Methodology for Project Development

The figure below shows the system flow for the Shape Grammar System

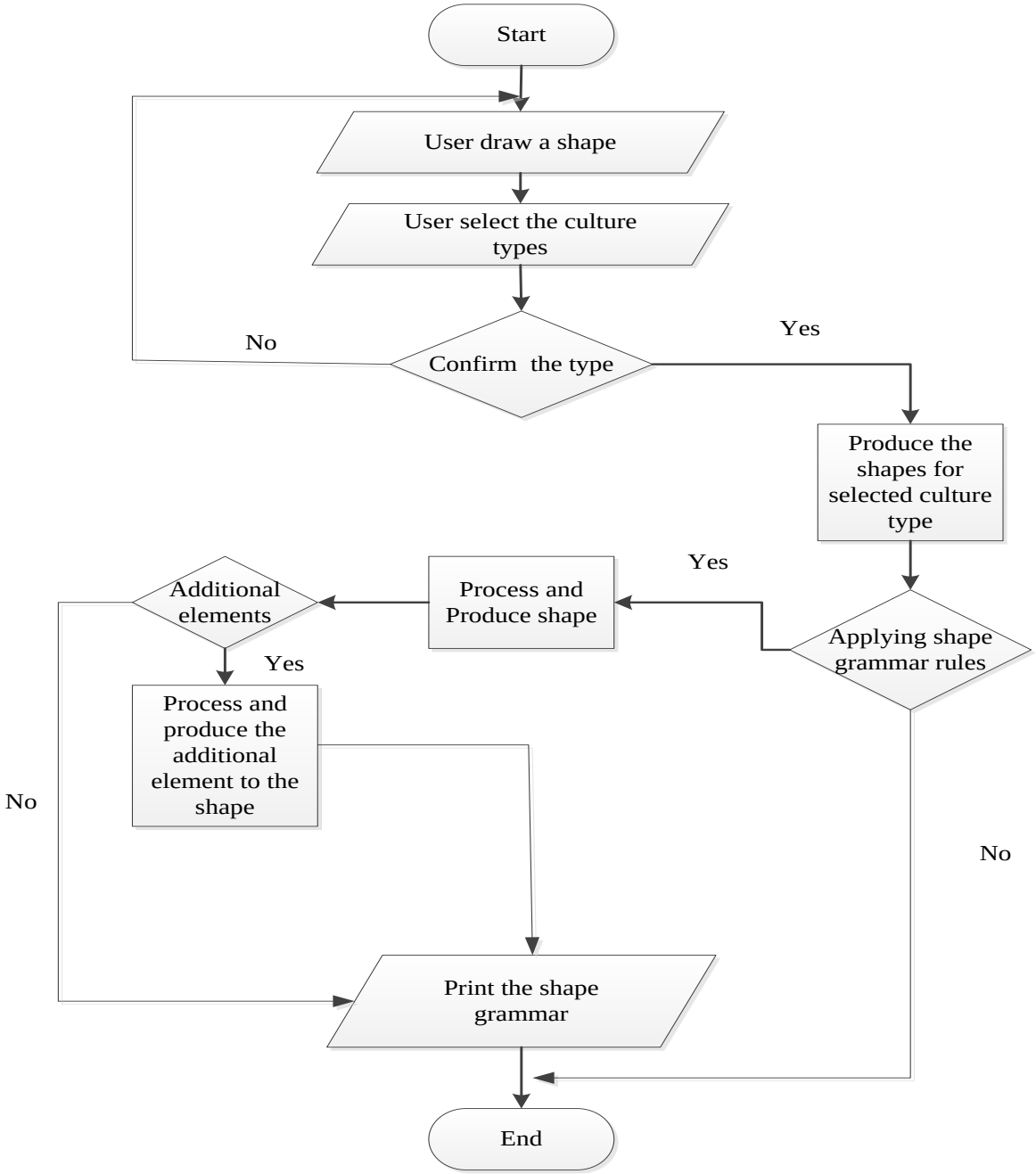


Figure 3.1: Flow of the shape grammar system

Step 1: Analysis

(4) Analysis of Educational Building

The analysis of existing educational building, such as the old educational building can be performed through the observation and also searching for the history recorded. From the observation, we get to know the details of the building design structure physically and its function. For example, the architectural structure information provides us useful information on how the building was designed.

Figure 3.2: High School Muar building

The figure 3.3 shown the educational building of High School Muar. This building was built in 1914 and was constructed according to the colonial-style.

(b) Analysis of Culture

The analysis of the culture will be performed through the study and understanding of the architectural concept and structure of a foreign country, for example, the Republic of China. These architectural concepts can be accessed from the publication of the architectural book materials, where different designer proposed their innovative ideas of culture through constructing the architectural building with different kinds of shape pattern. Furthermore, we can also searching the related information through online. Besides, we can also gather some of the requirements or opinions of the user through the distribution of survey forms. This

method also can help us to identify the user requirements more clearly on the design of educational building with cultural elements by using shape grammar.

Figure 3.3: Tiananmen Square, Beijing, China

Figure 3.4: Model Animal Research Center, Nanjing, Jiangsu

The figure 3.4 and 3.4 shown about the Tiananmen Square and the research centre. From both figures, we can find some similarity, that is both architectural building used square shape in their design. Besides, the roof design in Chinese culture has some curve up shape design.

(c) Analysis of Shape Grammar

The analysis of shape grammar was conducted from studying of various related journals and research articles, such as using shape grammar in product design, pattern formation, residential design and so on. From the study, we would get to know the basic framework on how the shape grammar be functioned. For example, we can refer to Figure 3.8 below where the kindergarten building in Finland was using shape

grammar technique in its building design. As a result, a modern and characteristic building was established.

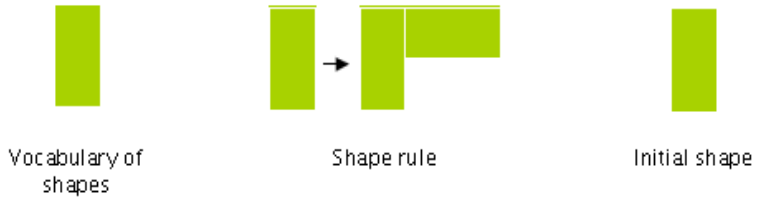


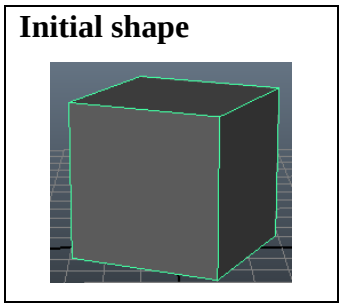
Figure 3.5: An example of a simple shape grammar

Figure 3.6: A few design derived from the simple shape grammar

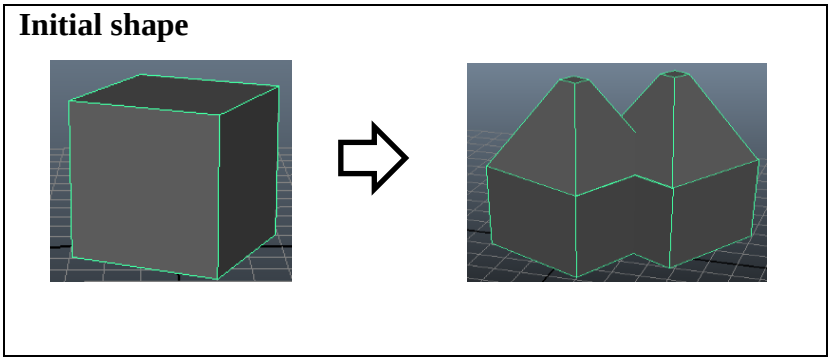
Figure 3.5 shows the application of shape grammar rule for simple shape.

Figure 3.6 shows the product of the derivation of shape grammar rules.

- There are several logical phases in developing and using the shape grammar.
  i. Create the shape
     - In this step, users will have to create any patterns of shape as an initial shape.



  ii. Compiling the grammar rules
     - In this step, the user will able to apply the shape grammar rule according to each of the cultural elements.



iii. Finalize for the shape grammar design

- In this step, user can save their desired shape grammar design structure.

Figure 3.7: The existing educational building of High School Muar

Figure 3.8: The kindergarten building design using shape grammar in Finland.

Step 2: Design the system

(a) Design system flowchart (refer to Figure 3.1)

(b) Design the system interface

- Additional buttons are added to the Autodesk Maya 2012, that are shape grammar and culture buttons, so that user can understand easily and use. (refer to APPENDIX B)

(c) Design the system database

First step :

All the shape grammar patterns will be designed and save accordingly in each of the cultural elements in the database.

Second step :

In the user interface, an additional column of shape grammar will be added, and this additional column will enable the user to select the different cultural elements.

Third step :

The shape grammar patterns will be retrieved from the database when user selected, and then, transform the initial shape of the shape that was being selected. Finally, the user can save the design educational building model into the database in Maya binary(.mb) format for future use.

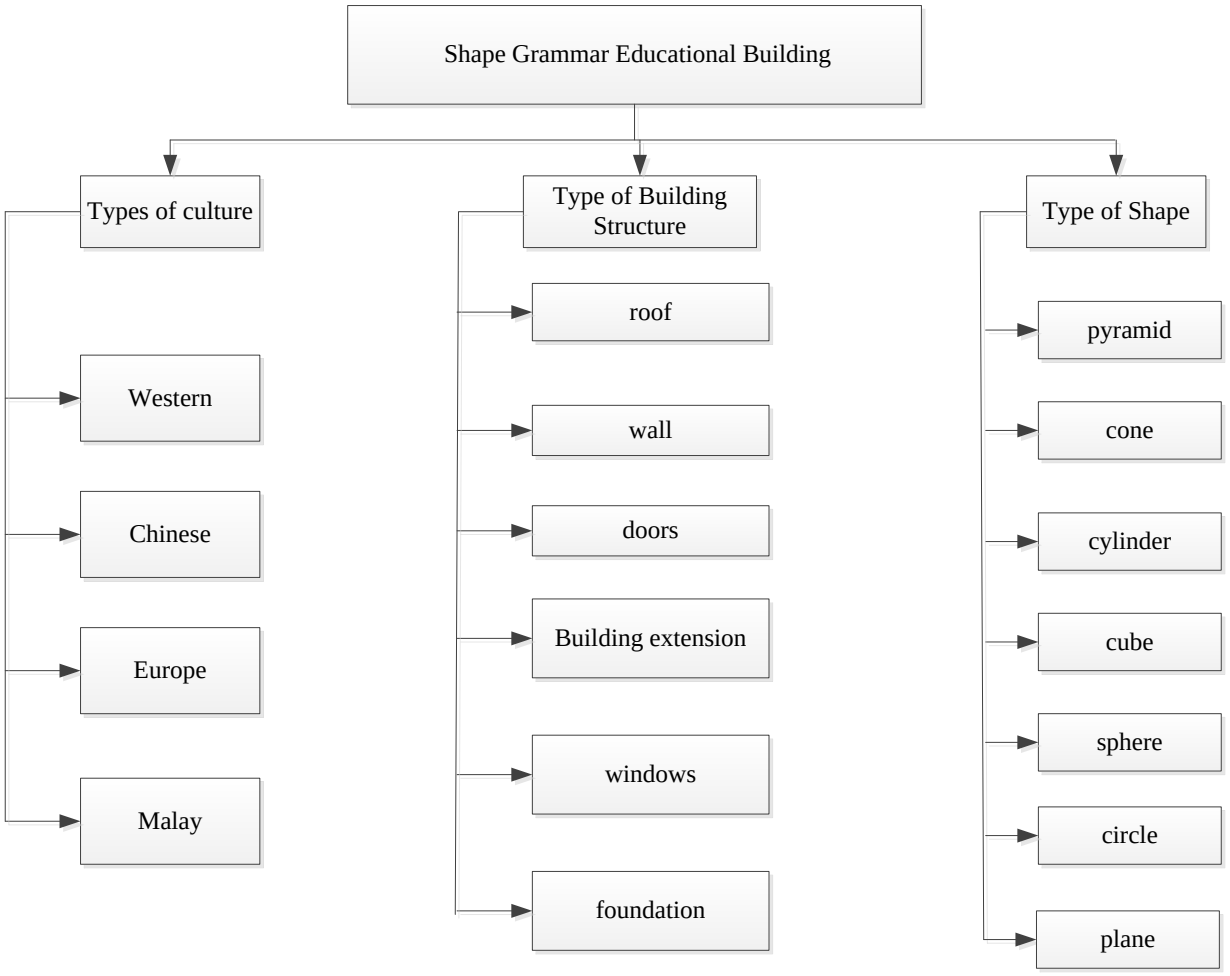


Figure 3.9 : Database Development for Shape Grammar Educational Building

(d) Design different shape patterns according to the types of cultural elements.

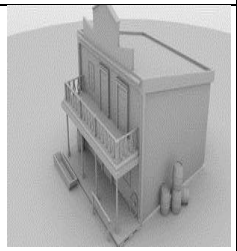
Cultural Type / Structures	Western	Chinese	Europe	Malay
Foundation	Vary	Vary	Vary	Vary
Walls	Plane	Plane	Plane	Plane
Doors				
Windows				
Roofs				
Building Exterior				

Table 1: Different cultural element in building structure